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Modeling the nonlinear financial relationship in selected ASEAN countries

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ABSTRACT

Both stock index and exchange rate play a crucial role as the financial assets that confronted with remarkable changes every day. The fluctuation of stock index and exchange rate is jointly dependent. The crucial reason to apply these time series data is because both the exchange rate and stock index are indicators of economic performance for a country. In the present study, a two component normal mixture model is fitted by statistical method in order to model the nonlinear financial time series data. Thus, the relationship between exchange rate and stock index is being explored via maximum likelihood approach. The empirical analysis employed provides evidence of a positive effect between exchange rate and stock index for Malaysia, Philippines, Indonesia and Thailand.

1. Introduction

Over the years, the interaction among exchange rate and stock index has drawn statistician and economists' attention since both of them play an essential role in affecting the development of a country's economy. Hence, the nonlinear financial data sets for the selected countries are explored via maximum likelihood in this study.

Exchange rate is the price for a country's currency that exchanged with to another currency of a country. The factors that influence exchange rate include inflation rate, trade balance, interest rate, political stability, internal harmony and quality of governance. The changes of exchange rate influence the flows of investment either the import or export prices for a nation's. A reduction in the exchange rate will reduce the export prices; however, a fall in the exchange rate will raise import prices. Furthermore, devaluation of exchange rate causes aggregate demand increase and creates job opportunity, in addition to increase the national output and gross domestic product (GDP). Rising of the exchange rate can reduce the excessive aggregate demand and control the inflation rates. Hence, the changes of the exchange rate might results in inflation or contribute to the economic appreciation.

Stock index or stock market index is a price that used to describe the market for the selected stocks or a company's value. It is crucial since it allows the investors and financial managers to benchmark the overall performance of the selected stocks. Furthermore, stock index is alternate every day and the changes may be affected by factors such as company news and performance, inflation, interest rates, world events and economic policy.

In the present study, maximum likelihood estimation is used to fit the finite mixture model in order to examine the nonlinear financial time series data. Finite mixture model is a probabilistic mixture model with finite-dimensional. Also, finite mixture model is increasingly getting attention over the years because of its flexibility in both practical and theoretical point of view. Therefore, this study applied maximum likelihood estimation to fit finite mixture model in which to evaluate the nonlinear model.

The structures of the present paper are as follows: Section 2 and 3 report the review of the past studies and the research methodology. Section 4 point out the sample and data that utilize and section 5 discuss the descriptive statistics for the variables; Section 6 discusses the results. Lastly, the paper concludes in section 7.

2. Review of literature

Recently, maximum likelihood estimation is widely applied by statistician because it provided efficient findings when the sample sizes are large; Moreover, it also able to estimate the asymptotically data sets or asymmetric business cycle.

According to Phoong and Ismail (2015), maximum likelihood estimation and Bayesian method are adopted to fit the finite mixture model in modelling the nonlinear time series data for the selected Asian countries. Findings revealed that

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there is a negative relationship between the rubber price and exchange rate for the selected countries.

Avdis and Wachter (2013) reported that maximum likelihood estimation is utilized to examine the equity premium or also known as expected returns in equities. The results showed that maximum likelihood framework is a reliable statistical method when the sample sizes are finite.

Cziráky (2005) applied maximum likelihood estimation to investigate the relationship between financial development and economic growth based on the 45 selected countries. The countries are divided into two categories that are developed and developing countries. These two categories are grouped based on the historical data that confronted with different financial development and economic growth situation.

Moreover, Liang (2009) applied maximum likelihood estimation and Bayesian method to fit the finite mixture model in modeling astronomy data. These two approaches are then compared with each other in which to evaluate the most plausible method among it. Findings revealed that both approaches provided similar results. However, maximum likelihood estimation is suggested to be used when a small sample size has. However, Bayesian method is suggested by Liang (2009) to estimate the large sample data.

Chumney (2012) applied and compared the performance of four statistical methods in estimated the structural equation modeling (SEM). The approaches includes maximum likelihood estimation, Bayesian method, partial least squares and generalized structural component. Due to the findings that observed, Bayesian method with unbiased properties is superior compare with other estimate methods when analysis involving large sample size data.

Additionally, Stewart et al. (2013) applied and compared maximum likelihood estimation and Bayesian method in examined the fisheries stock assessment models. The findings that obtained by Stewart et al. (2013) are different with Chumney (2012) since the findings from Stewart et al. (2013) explained that maximum likelihood estimation tends to have a lower median values in compared with Bayesian method.

However, the idea of Rashwan and Dereny (2012) has similarity with Chumney (2012). The application of Bayesian and maximum likelihood approaches are used to examine binary data for prostate cancer. Then, both approaches are compared with each other based on the performance of methods. Findings displayed that Bayesian method is plausible than maximum likelihood estimation because Bayesian method allows probabilistic interpretations to logistic coefficients and presents more accurate results.

Other statistical method that used to analysis the variables such as stock index can be referred to Phoong et al. (2013). Phoong et al. (2013) studied the changes of oil price and gold price on stock index by using Markov Switching Vector Autoregressive model. The findings found that oil price and gold price are the factors in affecting the stock index for Malaysia, Singapore, Thailand and Indonesia. Moreover, the MSI(2)-VAR(1) model enable to provide a significant and reliable results since it is able to fit and capture the smooth transition of the data series.

3. Maximum likelihood approach

Maximum likelihood approach is a powerful statistical method in which used to estimate the parameters for a model. Maximum likelihood approach with unbiased properties provides reliable findings for large sample sizes. Furthermore, it has efficiency characteristic because the parameter estimates that obtained normally have smallest variance in compared to others statistical method such as Bayesian method as the sample sizes increases. Apart from that, variance is a measure of how far the data set is spread out. If the variance that obtained is small, this reveals that the data points are close to the mean or expected value. Another advantage of applied maximum likelihood estimation is that when the sample sizes increases to infinity, it achieves the Cramer Rao lower bound. This illustrated that no asymptotically unbiased estimator has lower asymptotic mean square error than maximum likelihood estimation.

Maximum likelihood approach is a procedure for finding the values of one or more parameters based on the likelihood function that obtained in which to maximize the likelihood function. The application of maximum likelihood framework provides findings with asymptotically normal and asymptotically efficient. Asymptotically normal means the asymptotic distribution is normal distributed meanwhile asymptotically efficient is the efficiency in the limit as sample size tends to infinity. This method also provides a consistent approach to parameter estimation problems.

Moreover, maximum likelihood estimation is a famous approach which adopted to fit finite mixture model. Finite mixture model is a semi-parametric estimator of the density. Furthermore, finite mixture model also act as a mixture of other distributions in examined models. The application of mixture model is widely applied ranging from statistics to social science.

The general formula for maximum likelihood estimation is as follows:

$$L(\theta|x_1, \dots, x_n) = f(x_1, \dots, x_n|\theta) = \prod_{i=1}^{n} f(x_i|\theta) \quad (1)$$

where x_1,..., x_n denotes the independent and identically distributed observations with n samples. Then, the likelihood function, L is provided if the parameter is fixed. θ represents the vector of parameters for the model.

Likelihood function is superior to work with logarithm in which known as log likelihood and the formula is as follows:

$$\ln L(\theta|x_1, \dots, x_n) = \sum_{i=1}^{n} \ln f(x_i|\theta) \quad (2)$$

4. Research methods and population

The nonlinear financial time series data that adopted in the present paper includes returns of nominal exchange rate and stock market price for Malaysia, Thailand, Philippines and Indonesia. Nonlinear time series model act as a numerous model for economic and financial field. Thus, a model with nonlinear mean function with respect to parameter estimates depends on at least one other parameter. In general, relationship between dependent and independent variables can be computed using nonlinear estimation. Hence, nonlinear models that adopted in this study are stock index and exchange rate.

Both financial datasets that used in the present study confronted with great influence by Asian Financial Crisis that happened in mid-1997 (Essaadi et al., 2009). The main reason that affected the movement of equity and currency markets is because of Malaysia, Thailand, Philippines and Indonesia are the popular investment countries among Asian countries before the financial crisis happened. However, the Asian Financial Crisis triggered most of the Asian countries' economy. The countries that most influenced by the crisis include Thailand, Indonesia, South Korea, Philippines, Malaysia, Hong Kong and Laos. Meanwhile Singapore, Vietnam, Brunei, China and Taiwan were less influenced by the slump as compared to others.

In order to remedy the financial problems, most of the Asian countries fixed or float their currency to US dollar. Although the currency is then recovered, it is found that unable to return to its pre-crisis level. Therefore, the sampled data that collected for this study is from July 2005 until September 2012.

In this study, a two-component normal mixture model is obtained via information criterion and the step to compute number of components is listed in this section. Then, the normal mixture model is fitted by maximum likelihood estimation to model the non-stationary data. While the objective of this study is to investigate the interaction between nonlinear financial time series data including the exchange rate and stock index of Malaysia, Thailand, Indonesia and Philippines via statistical approach, maximum likelihood estimation.

There are some essential steps for the analysis. Firstly, the financial time series data such as stock index and exchange rate need to transform from non-stationary data to stationary data. Since most of the financial time series data are jump-diffusion model, therefore, it is known as non-stationary data. The behaviors for non-stationary data include trends, cycle, random walks or combination of these three. Furthermore, non-stationary is a common problem for time series data.

The analysis of non-stationary data provides unreliable findings and this lead to a poor understanding and forecasting. Moreover, this condition may lead to its mean and variance became not constant over the time, in addition to lags occurs. In order to remedy this weakness, the non-stationary data is needed to transform to become stationary data before the further analysis begin. Thus, the data are change to returns value.

Then, second step for the empirical analysis is identifying the number of components. The performance of this step play leading role to avoid invalidity of findings observed. Hence, information criterion such as Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) are applied in determining the number of components, *k* for the variables series. Moreover, both AIC and BIC are penalized-likelihood criteria that normally adopted to identify the plausible predictor subsets in regression. The general equation to compute AIC is:

$$AIC = -2In(m) + 2p \quad (3)$$

where *m* indicates the maximized value of likelihood function for the estimated model and *p* denotes the number of parameters for the model. The assumption of AIC is that the smallest value of AIC indicates that the model is preferable than others.

Bayesian information criterion (BIC) is another popular selection criterion that applied to identify the number of components for the model. The assumption of AIC and BIC is similar which is the smallest value of BIC denotes the model is superior to others. In general, the equation to compute BIC is:

$$BIC = -2In(m) + pIn(n) \quad (4)$$

where *m* represents the maximized likelihood function and *p* denotes the number of parameters to be examined. While *n* in the equation above denotes the number of observation for the estimated model.

Table 1 is the computed value of AIC and BIC along with number of parameters and log likelihood for the increasing number of components. According to Table 1, LL denotes the value of log likelihood that obtained meanwhile AIC and BIC represents Akaike Information Criterion and Bayesian Information Criterion respectively.

Based on the theory that described above, AIC and BIC with the smallest value denotes that the model is a better fits. Thus, *k*=2 option show smallest value of AIC and BIC in compared to others option. It can be concluded that a two-component mixture model with seven parameters is plausible in used for the further analysis. This findings seem reasonable because financial returns normally behave differently when normal situations and during crisis period (Phoong et al., 2013). Additionally, a two-component mixture model also known as jump-diffusion model.

5. Results and discussion

The empirical analysis employed provides that a two-component mixture model of the financial datasets with nonlinear properties is evaluated by using maximum likelihood approach. The sampled

countries that involved are Malaysia, Thailand, Philippines and Indonesia. The objective of the present study is to identify the relationship between stock index and exchange rate for the selected countries.

Table 1: Information based model selection criteria

Number of Component	Number of parameter	LL	AIC	BIC
$k = 2$	7	932.533	-1851.1	-1824.2
$k = 3$	11	922.267	-1822.5	-1780.3
$k = 4$	15	927.665	-1825.3	-1767.7
$k = 5$	19	930.898	-1823.8	-1750.8
$k = 6$	23	932.825	-1819.7	-1731.3

Note that the information tables that provided from FMM procedure are model information, optimization information and parameter estimates along with sampled countries in the following. The crucial role of model information table is to describe the basic information for the model; meanwhile the optimization information table is adopted to depict the basic information about the optimization setup. While the role for parameter estimates table is vital to show the findings for two-component mixture model which included normal model and a mixing probability model.

According to Table 2, the model of datasets is a two-component homogeneous regression mixture model with identity link function. This revealed that all the components in the model share the same family distribution and link function. Additionally, the data sets are normally distributed. A mixture of two normal models or a jump-diffusion model for financial datasets seems reasonable because it expressed differently in normal situations and during crisis period.

Table 2: Model information

Type of Model	Homogeneous Regression Mixture
Distribution	Normal
Components	2
Link Function	Identity

The second information table that provided from FMM procedure is the optimization information table which displayed at Table 3. Due to this table, the optimization technique that required for the analysis is Dual Quasi-Newton. Note that this technique is an algorithm that vital to find the local maxima and minima of the functions. Apart from that, Dual Quasi-Newton technique displays efficient findings when the sample size that used is medium or moderately large.

Others information that listed in Table 3 is the total number of parameters for the optimization. The output showed that there are seven parameters in the optimization includes four mean function parameters, two scale parameters and a mixing probability parameter.

From Table 3, four mean function parameters are comprise with mean of exchange rate and mean of stock market price for both component 1 and component 2. While for the two scale parameters that obtained denotes the variance for component 1 and component 2. Since the number of components is two, therefore, a mixing probability parameter is required to demonstrate probability density function for the model. Note that all optimization parameters are then expressed in parameter estimates model table.

Table 3: Optimization Information

Optimization Technique	Dual Quasi-Newton
Parameters in Optimization	7
Mean Function Parameters	4
Scale Parameters	2
Mixing Probability Parameters	1

Lastly, the information table that provided from FMM procedure is parameter estimates model table. Since the model is fitted by more than one component, parameter estimates for mixing probability table is provided. Then, the parameter estimates for normal and mixing probability table along with the sampled countries are collected and summarized in Table 4 and Table 5 respectively. The parameter estimates for normal model in Table 4 demonstrated the six parameters for normal model which includes four mean function parameters and two scale parameters. Otherwise, the parameter estimates for mixing probability model along with each country is listed in Table 5.

In addition, Table 4 pointed out the information of parameter estimates for six parameters along with the countries. As referred to Table 4, it can be concluded that the alteration of exchange rate influence the stock index for Malaysia, Thailand, Philippines and Indonesia. Note that the estimated intercept represents the mean for exchange rate meanwhile estimated index denotes the mean for stock index. This is because exchange rate and stock price displayed positive effect for all selected countries. Positive effect implied that exchange rate will depreciate when the stock index decrease or vice versa.

The findings obtained can be supported by referred to Granger et al. (2000) that the depreciation of currency leads to a lower stock market index for some Asian countries such as Indonesia, Malaysia, Philippines, Korea, Singapore, Japan and Taiwan. Additionally, Mishkin (2001) also supported the findings of the present study that the exchange rate and stock market price showed positive relationship.

Apart from that, the variance for both component 1 and component 2 for all sampled countries are small and this illustrated that the value is closed to

mean. Hence, the outputs that obtained can be concluded as valid, reliable and significant.

Table 4: Parameter estimates for normal model

Number of component	Effect	Estimate	
		Malaysia	Thailand
1	Index	-1.4255	-1.7375
1	Intercept	0.0119	0.00978
2	Index	-2.4944	-15.1370
2	Intercept	-0.00149	-0.3352
1	Variance	0.00316	1E-8
2	Variance	0.00043	0.00409
Number of component	Effect	Estimate	
		Philippines	Indonesia
1	Index	-1.4437	-1.4273
1	Intercept	0.0139	0.0360
2	Index	-6.9466	-5.3432
2	Intercept	-0.0111	-0.0602
1	Variance	0.00265	0.00152
2	Variance	0.00245	0.00244

Table 5: Parameter Estimates for Mixing Probabilities

Effect	Estimate			
	Malaysia	Thailand	Philippines	Indonesia
Estimate	-0.0519	4.4427	2.0448	1.2895
Mixing probabilities	0.4870	0.9884	0.8854	0.7841

Furthermore, the mixing probability or weight that listed in Table 5 can be used to compute the probability density function for each country. The mixing probability in last row of Table 5 represents the weight for component 1. In order to measure the weight for component 1, the estimate effect in mixing probability table adopted to measure weights for component 1. For instance, the formula to compute weight for Malaysia is:

$$Mixing\ probability = \frac{\exp(-0.05198)}{\exp(-0.05198)+1} = 0.4870 \quad (5)$$

The total weight or mixing probability for all components is equal to one. Thus, the findings above described that the probability density function for Malaysia is $0.4870f_1 + 0.5130f_2$ and Thailand is $0.9884f_1 + 0.0116f_2$. Additionally, the probability density function for Philippines is $0.8854f_1 + 0.1146f_2$ meanwhile for Indonesia is $0.7841f_1 + 0.2159f_2$ where f_1 and f_2 denotes the probability density function for component 1 and component 2.

6. Conclusions

The present study adopted maximum likelihood estimation to evaluate a mixture of univariate distribution in order to estimate the relationship between stock index and exchange rate for Malaysia, Thailand, Philippines and Indonesia. The parameters in maximum likelihood estimation are fixed but unknown. Moreover, maximum likelihood estimation play role as maximize the likelihood function to measure the parameters. Thus, this study obtained a two-component normal mixture model in order to establish the interaction among nonlinear financial time series data via maximum likelihood estimation. As referred to the findings that obtained, it can be concluded that there is a positive impact between exchange rate and stock index for Malaysia, Thailand, Indonesia and Philippines. The main reason that leads to the finding is both parameters are jointly dependent. Additionally, probability density function for all sampled countries also provided.

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